Formosat-2 Satellite Imagery Assessment for Coastal Ecosystem Mapping in Western Coast of Banten, Indonesia

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ABSTRACT

Coastal ecosystems in West Banten are valuable, providing products and services for the livelihood of its community, and highly threatened. Threats facing coastal ecosystems in West Banten are rapid growth of coastal populations, increasing exploitation of coastal resources, alteration and loss of habitats, also high runoff carrying sediment and other terrestrial-based pollutants from coastal rivers. Mapping of coastal ecosystems will provide significant baseline data for future monitoring and sustainable management of coastal ecosystems in West Banten. Using FORMOSAT-2 data obtained on August 9, 2007, we assess current condition of coastal ecosystems in West Banten area on August 9-11, 2007. Using both data from FORMOSAT-2 satellite imagery and from field assessment, with this paper we exposed map featuring six class of coastal cover-area in West Banten. This study also measured spectral reflectance from 24 objects in West Coast of Banten.

Keywords: FORMOSAT-2, coastal, map, Banten

1. INTRODUCTION

Most of border area in Banten Province, located in 5° 7' 50" - 7° 1' 11" S and 105° 1' 11" - 106° 7' 12" E, represent coastal environment with complex use of its resources (DEPKIMPRASWIL 2003). West Coast of Banten bordering with the Sunda Strait is subject to marine tourism, transportation, industry, fisheries, and conservation. Up to this day a great variety of human activities happen there simultaneously. The main environmental impacts consist of alteration and loss of coastal habitats due to resource exploitation and development, organic and inorganic pollution, volcanic eruption from the Krakatau, and tsunami. Scientific data on coastal ecosystems, land use, landforms, and shoreline and water quality are required periodically to ensure an environmentally effective coastal zone management practices. Maps on various coastal themes form basic input to the coastal zone management models. Conventional maps are quite useful; however, they do not provide up-to-date information. Since coastal zone is very dynamic, periodic mapping is vital for planning effective strategies.

The interpretation of remotely sensed data is the best tool currently available for providing synoptic spatial information on various scales and with reasonable classification and control accuracy. The availability of FORMOSAT-2, which produced hyperspectral data with spatial resolution of 8 m for multispectral and 2 m for panchromatic images, is expected to provide spatially comprehensive coverage at a higher resolution for effective and accurate analyses of different coastal ecosystems exist within one area. There are five spectral bands in FORMOSAT-2, i.e. P: 0,45–0,90µm (panchromatic), B1: 0,45–0,52µm (blue), B2: 0,52–0,60µm (green), B3: 0,63–0,69µm (red), and B4: 0,76–0,90µm (near-infrared). The objective of this research is to test the ability of FORMOSAT-2 data in producing coastal geospatial data, particularly for mapping of coastal ecosystems, i.e. mangrove forests, seagrass beds, and coral reefs, in West Banten area.

2. METHODS

2.1 Study sites

This study was conducted on August 5-7, 2007, in coastal area of West Banten, with geographic reference of 6° 15' 40" - 6° 41' 30" S and 105° 35' 00" - 106° 00' 00" E. West Banten coastal platform extends north-south, bordered with Sunda Strait and is influenced by volcanism activities from Mount Krakatau. Thus, its shorelines and living coral communities were geologically incipient (Tomascik et al 1997). There were two small islands located near the coasts of West Banten, i.e. Popoleh Island and

Karang Gosong Island. There were 22 study sites, particularly to obtain seawater samples, including 3 sites for coral assessment and 1 site for mangroves and seagrass assessment (Figure 1).

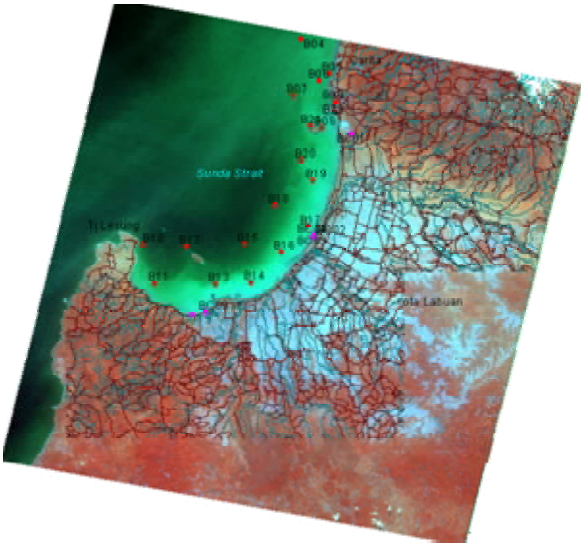


Figure 1. Study sites

2.2 In-situ sampling

In general, *in-situ* sampling conducted comprises of coastal ecosystem assessment and spectroradiometric measurements of sediment types and species. Assessed coastal ecosystems were mangroves, seagrass beds, and coral reefs, which techniques were based on English et al (1997). Reflectance measurements were made to create a spectral library of 24 reflectance spectra encompassing mangroves, other coastal vegetation, fishponds, several types of coastal-substrates and different colors of seawater.

2.3 Satellite image analysis

Morphologies of the beaches, lagoons, mangrove forests, seagrass beds, and coral reefs were classified on the basis of the spectral signatures of their various habitats using images produced from FORMOSAT-2 satellite image obtained on August 9, 2007. Geometric correction was trained with existing ground-truth data and reference map from BAKOSURTANAL were performed using ER Mapper and Arc View (Green et al. 2000).

3. RESULTS AND DISCUSSION

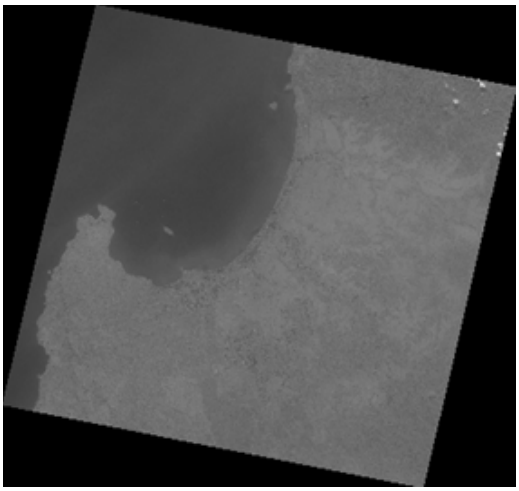
3.1FORMOSAT imagery

The main remote sensing mission for FORMOSAT-2, which was launched in 2004, was to capture satellite images of the Taiwan Island and the surrounding islands and ocean to monitor the environment and its resources. Later on, under international collaborative agreement, FORMOSAT-2 was also used to capture images of other regions in the Asia Pacific. Within the frame of APEC SAKE on Satellite Application on Fishery and Coastal Ecosystem (SAFE), FORMOSAT-2 acquires capture satellite images of Indonesian coastal and archipelagic waters (Figure 2).

Figure 2. Satellite images of West Banten producedby FORMOSAT-2,
□ = acquisition date July 7, 2006 and
□ = acquisition date August 9, 2007.

On July 7, 2006, FORMOSAT-2 captured the first satellite image of West Banten. Due to stripping error, the images were incapable for further processing. One year later, FORMOSAT-2 acquires another image of West Banten on August 9, 2007. Panchromatic FORMOSAT-2 images of West Banten are presented in Figure 3, while multispectral FORMOSAT-2 images of West Banten are presented in Figure 4.

(a)



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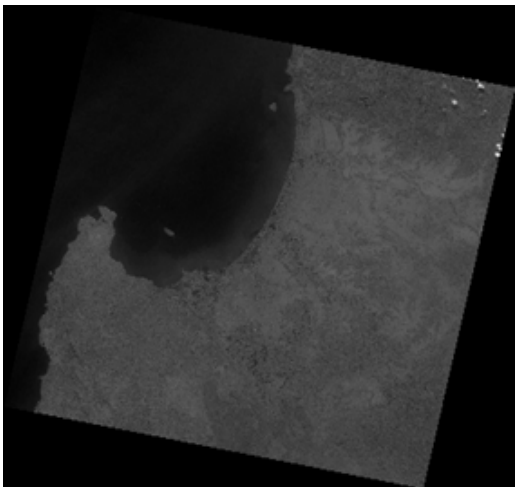
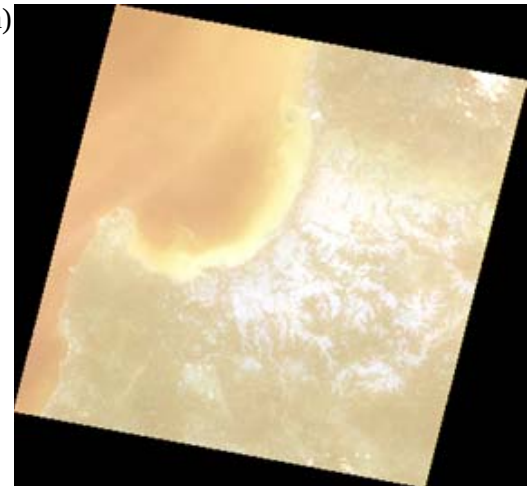


Figure 3. Panchromatic FORMOSAT-2 image of West Banten, (a) prior to geometric correction and (b) after geometric correction.

(a)



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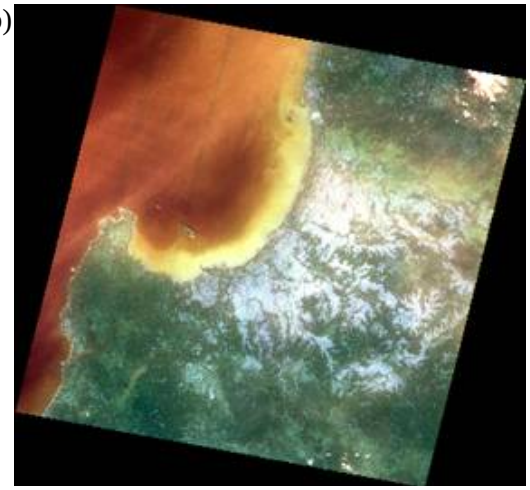


Figure 4. Multispectral FORMOSAT-2 image of West Banten, (a) prior to geometric correction and (b) after geometric correction.

3.2 Coastal ecosystems of West Banten

Coral communities in West Banten are influenced by volcanism and extreme sedimentation due to lots of river discharges, thus resulting in patchy distribution and no significant carbonate accretion to form fringing reefs as if before 1883 Krakatau eruption (Tomascik 1997). From three observed sites, i.e. Popoleh Island, Karang Gundul, and Karang Gosong, the highest cover of hard corals were available in Karang Gundul (43.0%). Benthic communities in Popoleh Island were dominated by soft corals of *Lobophytum*, while calcareous macroalgae of *Halimeda* were common in Karang Gosong (Figure 5). Common Scleractinian corals observed were *Acropora, Pocillopora, Stylophora, Porites, Favia,* and *Montipora*.

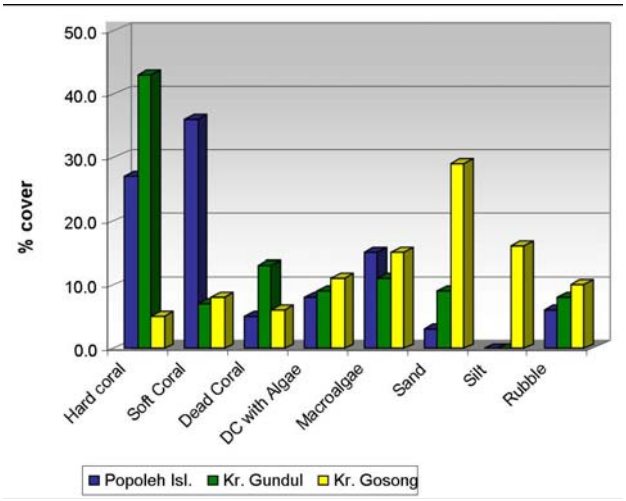


Figure 5. Results of coral reef assessment in West Banten

There was only one species of seagrass observed in the study sites, *Enhalus acoroides*, which is the largest species of seagrass. In relation to general feature of study sites, existing silty to muddy sediments support *Enhalus* to form monospecific meadows. Mangrove vegetation in study sites comprised mainly of *Rhizopora* and *Bruguiera*. Other mangrove species observed in the surroundings were *Avicennia, Sonneratia, Xylocarpus, Ceriops*, and *Exoecaria*.

High resolution (8 m) classification map was generated for coastal environment of West Banten, Indonesia, from a mosaic of FORMOSAT-2 multispectral images to produce six classes (Figure 6). Contrast-stretched, multi-spectral image maps provided a qualitative method to distinguish different types of seawater (deep, shallow, and high turbid waters), mangrove forests, bushes and

other coastal land-vegetation, also rice fields and housings. This map, in a geographic information system (GIS) format, can be used for fieldwork, as base maps for other scientific studies and for management of coral reef ecosystem.

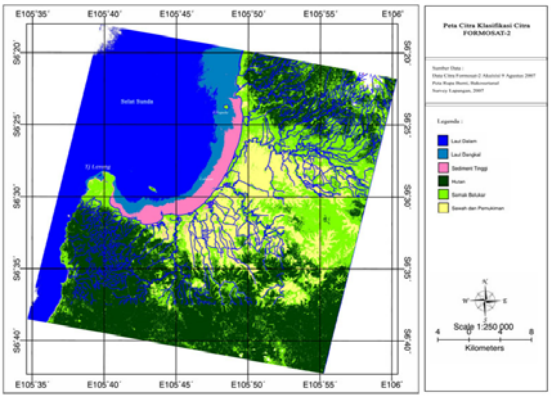
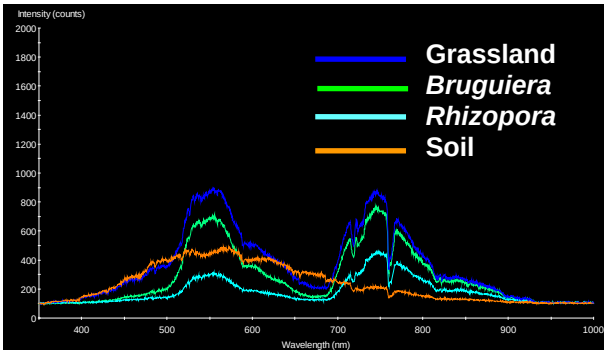


Figure 6. Classified map of coastal environment in West Banten, using multispectral FORMOSAT-2 image with spatial resolution of 8 m.

High resolution (8 m) classification map was generated for coastal environment of West Banten, Indonesia, from a mosaic of FORMOSAT-2 multispectral images to produce six classes (Figure 6). Contrast-stretched, multi-spectral image maps provided a qualitative method to distinguish different types of seawater (deep, shallow, and high turbid waters), mangrove forests, bushes and other coastal land-vegetation, also rice fields and housings. This map, in a geographic information system (GIS) format, can be used for fieldwork, as base maps for other scientific studies and for management of coral reef ecosystem.

3.3 Spectroradiometric measurements

In-situ spectroradiometric measurements play an important role in the development of remote sensing applications, bridging the gap between laboratory optical measurements and measurements from satellite platforms (Dekker et al. 1992). Therefore, this study also measure reflectance properties of various objects. Averaged reflectance spectra for the coastal vegetation, including two species of mangroves, different types of coastal substrates, fishponds, and different types of seawater are shown in Figure 7.



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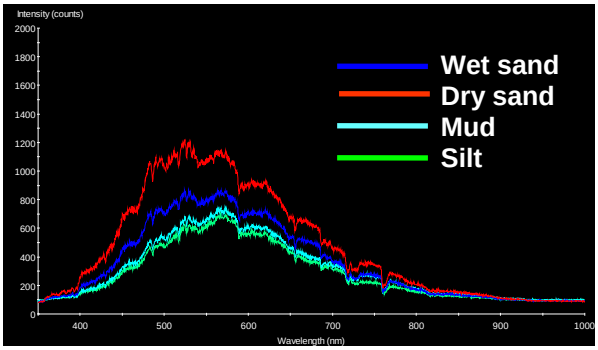

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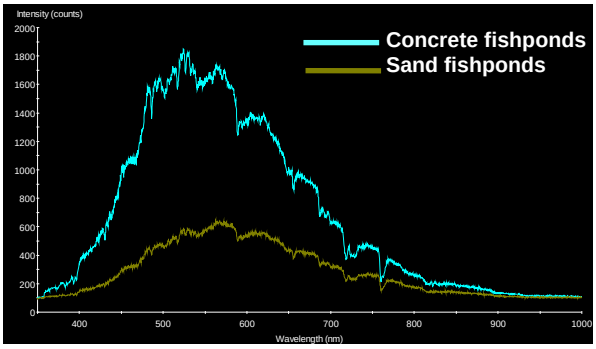

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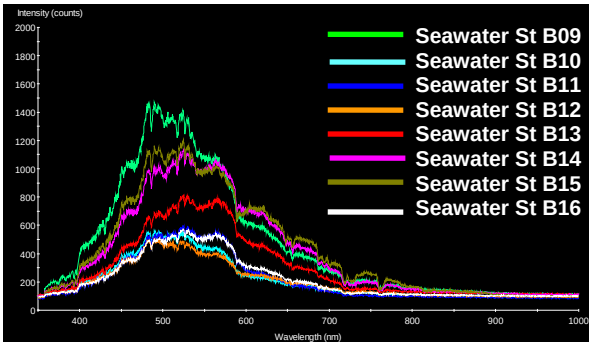

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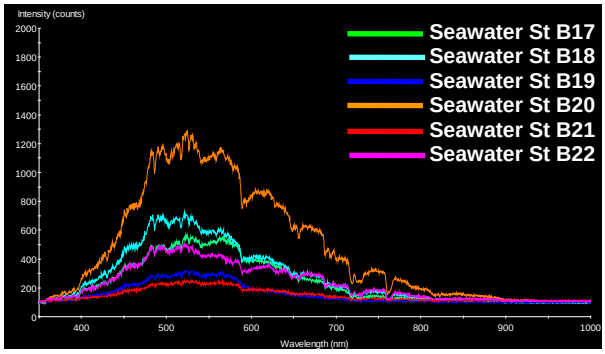

(e)

Figure 7. Observed spectral reflectance of coastal vegetation (a), coastal substrate (b), fishponds (c), and different types of seawater (d, e).

There were two types of fishponds for reflectance measurement, i.e. concrete-based and sand-based. The concrete fishponds spectra had the highest reflectance values (Figure 7c). The coastal vegetation had lower reflectance compared to different coastal land-substrate (Figure 7a and 7b). This indicated that bare sediment around the coasts could be easily separated from other bottom types on the basis of brightness alone.

All coastal vegetation showed a reflectance maximum at around 750 nm, and mangrove reflectance spectra showed the most variation in shape and magnitude within species in comparison with the other groups (Figure 7a). Within them *Rhizopora* had the lowest reflectance values and the least variation in spectral shape (Figure 7a). Figure 7d and 7e illustrate that turbid seawaters have higher reflectance in comparison to clear seawaters. All turbid seawaters exhibit a reflectance maximum at around 500 nm.

4. CONCLUSION

FORMOSAT-2 is able to provide high-quality satellite images for coastal environment mapping. Results from spectroradiometric measurements indicate that:

(1) for the purpose of medium (community) and fine (species) vegetation mapping, it is best to use spectral band B2 and B4 of FORMOSAT-2.

(2) for the purpose of coastal seawater and sediment mapping, it is best to use spectral band B1 and B2 of FORMOSAT-2

(3) for the purpose of fish ponds mapping, it is best to use spectral band B2 and B3 of FORMOSAT-2

ACKNOWLEDGMENTS

This research was supported by the Agency for Marine and Fishery Research of the Indonesian Ministry of Marine Affairs and Fisheries, Department of Marine Science and Technology of Bogor Agricultural University, Agency for the Assessment and Application of Technology, and counterparts in Chinese Taipei especially in providing valuable FORMOSAT-2 data. The assistance of several colleagues during fieldwork is gratefully acknowledged. Special thanks to Adriani whose comments were greatly appreciated in contributing to the final form of this paper.

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Opening Speech

Dear Chairman of Agency for Marine and Fisheries Research; Friends and Colleagues, Ladies and Gentlemen, Good morning!

It is a great pleasure for us to host this "second **APEC SAKE** (Satellite Applications on Knowledge-based Economy)". I would like to express our warm welcome to all of you, especially to the Delegation from National Taiwan University, National Cheng Kung University, Vietnam National University, University of the Philippines, Tokyo University, Nagoya University, Collect Localisation Satellite, ITB, and LIPI.

SAKE project started since 2006, it is the continuation of OMISAR project. The objective of this workshop is to give the opportunity to draw together the researches and stakeholders of the Asia Pacific countries and to promote application of satellite remote sensing for marine conservation and ocean resources sustainability. This program consists of 2 workshop days and 2 days of technical tour to Banten area. This workshop is in cooperation of BRKP –DKP.

I have been informed that SAKE project will continue until 2008 with the focus of activity in the Derawan Island in South Kalimantan and Pangkajene Islands in South Sulawesi. The objective is to develop algorithm for coral reef and seaweed mapping using the Formosat-2 satellite and hyperspectral images. These activities will be beneficial for efforts in monitoring the coastal ecosystem, identification of marine resources and support the local community in preserving the habitat.

In this opportunity, I would like to thank to all organizer committee members from BPPT, to all organizations and all sponsors who have provided their effort to make this workshop become a success. I hope this workshop will help greatly increase the capability and knowledge of the scientists on very high resolution images and to expose the capability of hyperspectral technology to support natural resources management in Indonesia.

I also hope the cooperation between BPPT and Institutions of Chinese Taipei does not stop here, but will continue in the next coming year.

Finally, I wish this workshop a great success and wish you a good time in Jakarta. And with saying Bismillahirahmanirahim, the second APEC Satellite Applications on Knowledge-based Economy workshop is officially opened.

Thank you.

Prof. Ir. Said D. Jenie, Sc.D.
Head of Agency For the Assessment and Application of Technology (BPPT)
Republic of Indonesia
Jakarta, 5 November 2007

Contents

Appendix II: Summary of Panel Discussion

Panel members: Dr. Aryo Hanggono, Dr. Nani Hendiarti, Prof. Cesar Villanoy and Prof. Cho-Teng Liu

Summary:

We are grateful to BPPT and BRKP in organizing this SAKE-2 workshop successfully. This is the major activity of SAKE 2007 project. The number of participating scientists, number of countries that these scientists came from, the number of presented papers, and the depth of research results are all unprecedented in SAKE and all OMISAR projects.

SAKE 2008 proposal has been approved by APEC MRCWG, and by APEC Budget Allocation Committee. About 8 proposals submitted to MRCWG in April, only two proposals were funded by APEC, and SAKE 2008 is one of them.

The Steering Committee of SAKE 2008 project will work closely with participating scientists to acquire more Formosat-2 images to meet their needs of research. The next meeting of Steering Committee will be hosted by Dr. Khu in Viet Nam

The next SAKE workshop is planned at Manado, Indonesia. Wish you all join us and present your study in the application of satellite images.

As shown in the welcome speech by Dr. Indroyono, corals are sensitive to global climatic changes. Nearly 50% of world corals were bleached in the last El Nino. Because it is a breeding ground of most marine species, and its biodiversity is the largest in all marine ecosystems, mapping coral communities in the global oceans and monitoring coral health are important to the conservation of marine resources. Working with Coral Triangle Initiative will be the first goal of the new proposal that is a follow-up of SAKE 2008 project. The new proposal to APEC Marine Resource Conservation Working Group will be drafted from now to February 2008.

The second goal of the new proposal will be the monitoring of oil spill in operational mode. This will assist the assessment of damages in near-real time fashion, the prediction of the movement of oil patches, and the allocation of the limited resources for mitigating disaster and for reducing damages to marine resources.